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MAY 15 1920 SERIAL NO. 203

THE MENTOR

THE STORY OF CHEMISTRY

By
FLOYD L. DARROW

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DEPARTMENT OF SCIENCE

VOLUME 8
NUMBER 7

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Discovery and Invention

There is a difference between discovery and invention. A discovery brings to light what existed before, but what was not known; an invention is the contrivance of something that did not exist before.

Many people, probably most people, think that, when a discovery is made, it comes all in a flash, as it were—that a new idea suddenly crops up, and its conception is a discovery. That may sometimes be the case.

We have all heard of the puzzle given to Archimedes; how he was asked to find out, without injuring it in the least, whether a certain crown consisted of silver or of gold; and by weighing it in the air and in water, he invented the method of taking specific gravity; for the crown when weighed in water lost weight equal to that of the water which it displaced. And he ran through the streets of Alexandria, crying, "Eureka! I have found it!"

His finding that the crown was of gold was a *discovery;* but he *invented* the method of determining the density of solids. Indeed, discoverers must generally be inventors; though inventors are not necessarily discoverers.

It is usually the case that discoveries have to be accompanied by inventions; the sequence is that to try any new thing, a piece of apparatus has to be devised which will effect the purpose—or perhaps an apparatus already known has to be altered—so that it may almost be said that invention and discovery go hand in hand.

Sir William Ramsay.

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THE MENTOR IS PUBLISHED TWICE A MONTH

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MAY 15, 1920 VOLUME 8 NUMBER 7

Entered as second-class matter, March 10, 1913, at the postoffice at New York, N. Y., under the act of March 3, 1879.

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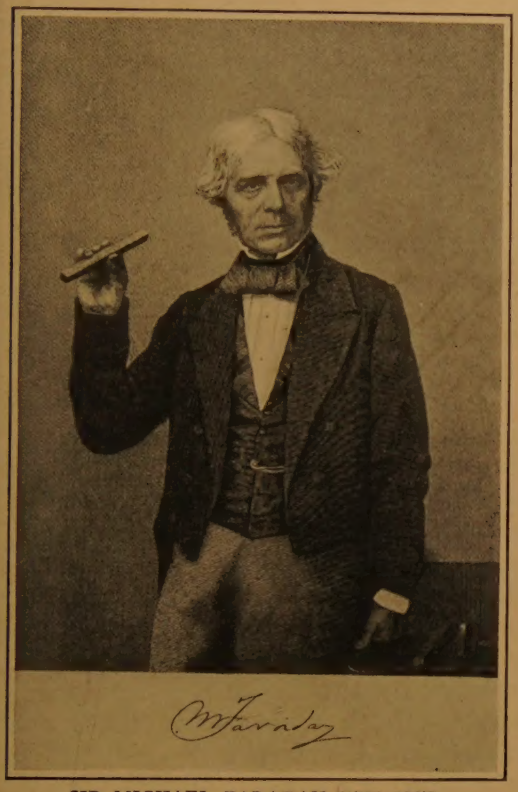
THE MENTOR · DEPARTMENT OF SCIENCE
SERIAL NUMBER 203



SIR MICHAEL FARADAY (1791–1867)
The first great physical chemist

THE STORY OF CHEMISTRY

By FLOYD L. DARROW

Head of Science Department, Polytechnic Preparatory School, Brooklyn, N. Y.

MENTOR GRAVURES

THE ALCHEMIST, By Teniers
SIR HUMPHRY DAVY
SIR WILLIAM PERKIN
ALFRED NOBEL
SIR WILLIAM RAMSAY
MADAME CURIE

TO tell the story of chemistry is to trace the material, and to a very large extent the intellectual, progress of the race from early beginnings to the present moment. For whether its activities be under the influence of the "ancient rule of thumb," or subject to the sway of the finger of modern science, chemistry has been the handmaid of industry and a mother of philosophical speculation.

The Egyptians, Phoenicians, Jews and other ancient peoples had a certain accidental and empirical* knowledge of applied chemistry. Indeed, the works of architecture, the weapons of warfare and the utensils of the domestic arts of those early civilizations would have been impossible without this knowledge. The metallurgy of the simple ores, viz.: gold, silver, copper, iron, lead and tin, was a highly perfected art. As the "bronze age" of primitive history bears testimony, a number of their alloys had been known for many centuries. The manufacture of glass

*Empirical knowledge is knowledge based on experience and observation rather than on scientific research.

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ROGER BACON (1214–1294)
Philosopher, Alchemist and originator of experimental research

and its artificial coloring, tell us of the marvelous skill of these early workers. The preparation of soap, dyes and pigments, numerous medicines, oils and perfumes goes back to prehistoric times. A knowledge of fermentation, too, was one of the earliest possessions.

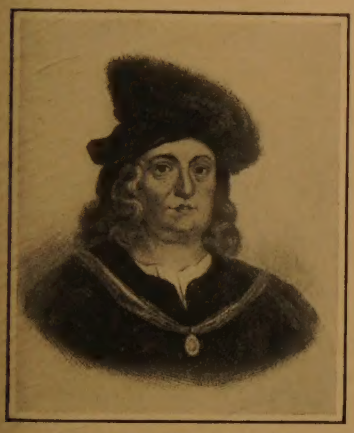
The Greeks contributed nothing to chemistry. Their deep aversion to experimentation, coupled with their genius for speculative philosophy, dealt a death blow to any scientific progress, and the pernicious influence of their early teachings had a withering effect all through the Middle Ages. Instead of proceeding from the known to the unknown and building their speculations upon personally acquired facts, the Greeks attempted to evolve the structure of a universe by intellectual processes alone. But their hypotheses were only guesses. Thus Democritus put forth a theory of the atoms, wonderfully similar to our modern view, but it had no relation to observed facts and was only a happy coincidence.

The long period of alchemy extending from the third century of our era to the middle of the sixteenth, and even in isolated instances to the closing decades of the nineteenth, prevented the beginnings of chemistry as a true science. Born in Egypt and carried by the Arabs into Spain and Central Europe, this false science swayed both church and state and numbered among its devotees such figures as Geber the Arabian, Basil Valentine, Albertus Magnus, Roger Bacon, Raymond Lully, Thomas Aquinas and many more. But the alchemists made little progress towards explaining the chemical processes already known to the ancients. Scarcely any advance was made in the metallurgy of the ores. The art of dyeing remained stationary. A little progress was made in pottery and glass manufacture and a few new medicines came into use. There was some extension of the knowledge of artificially prepared compounds, but still the utmost confusion prevailed as to their real nature. Alchemy, however, represented one very great gain. It turned aside the current of pure speculation and gave a tremendous impulse to the actual working with substances. As a result great skill in manipulation was acquired and also a knowledge of fundamental chemical processes.

GEORG ERNST STAHL (1660–1734)
Father of the Phlogiston theory of Combustion

Iatro Chemistry

Iatro, or medical chemistry, representing a transition period between the vagaries of alchemy and the beginnings of a rational chemistry, marks a great advance. This period centers about the picturesque figure of Paracelsus and extends from the first quarter of the sixteenth century to the middle of the following century. Paracelsus taught that "the object of chemistry is not to make gold but to prepare medicines." Retaining the three elements of the alchemists, mercury, sulphur and salt, he extended his conception to include animal and vegetable matter as well, and held that the health of the human organism depended upon the maintenance of a proper balance between these ingredients. Illness was due to a disturbance of this relation, and the patient might be restored to health by supplying the particular element of which there was a deficiency. Whether by accident or otherwise, Paracelsus became celebrated for many wonderful cures and was invited to occupy the chair of Medical Science at Basle, Switzerland, where, with great originality and an arrogance characteristic of the man, he promulgated his new ideas. Eventually driven from this position, he wandered about Europe preaching and practicing his doctrines until his death in wretched circumstances in 1541.

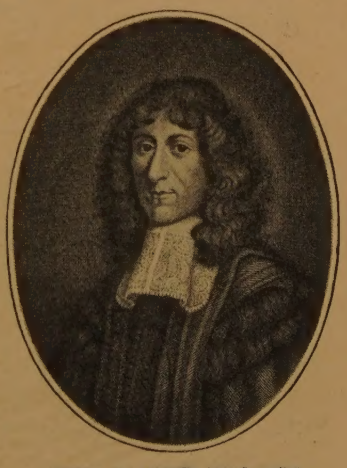


PARACELSUS (1493–1541)
Father of medical chemistry and first notable opponent of alchemy

The great service rendered by iatro-chemistry consisted in turning chemical investigation into new and useful channels. The apothecary shops of Europe were transformed into research laboratories, in which, under the stimulus of preparing new medicines, many important discoveries were made. This was the heroic age of medical science and drugs of the most poisonous nature were freely used. Indeed, the poisonous properties of many of them were discovered in this way.

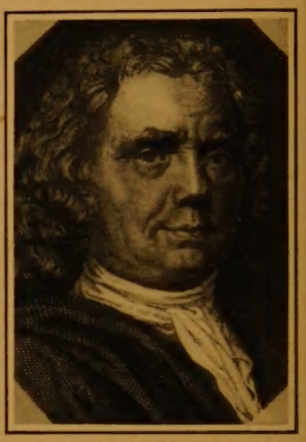
The Phlogiston Period

In Robert Boyle, seventh son of the Earl of Cork, chemistry found a real creative genius, who, breaking free from the fetters of Aristotle and Paracelsus, blazed a new path in the third, or Phlogiston, Period of the science. Unhampered by the superstitions of alchemy and the crudities



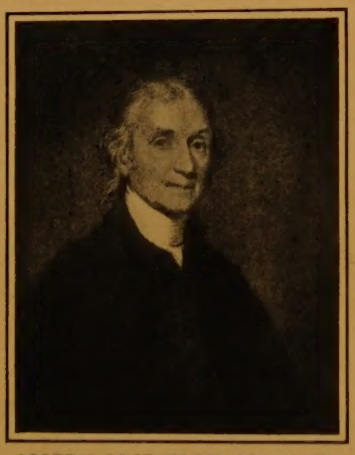
JOHN MAYOW (1643–1679)
He anticipated the discovery of oxygen by a hundred years

of the iatro-chemists, Boyle recognized for the first time the undoubted existence of many elementary substances and numerous compound bodies. But above all he, first among chemists, boldly proclaimed that chemistry should be studied for its own sake, and not because of any possible aid to the alchemist or the physician. In his efforts to determine the real composition of bodies, he may rightfully be regarded as the father of analytical chemistry. Although he recognized that a metal upon being heated in the air gains weight, he did not find the key to the explanation of this fact, but believed in a fire stuff having weight, which was taken up in the process.

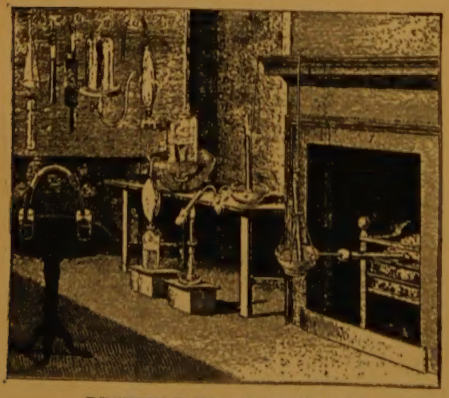


HERMANN BOERHAAVE
Famous Dutch chemist (1668-1738)

Man's first great conquest of Nature was demonstrated in his mastery of fire. Regarded with awe and superstition by primitive peoples, its explanation was always a perplexing problem. But the progress of modern chemistry was impossible until the mystery of combustion should be explained. Combustion enters so vitally into chemical processes that a knowledge of it is fundamental to their understanding. A man who came very close to arriving at a solution of this problem and who might have forwarded the progress of the science by one hundred years, had it not been for his early death, was John Mayow. His keen observation, recognizing in the air a substance which supports combustion, unites with metals and changes venous to arterial blood, thereby anticipated the discovery of oxygen.



JOSEPH PRIESTLEY (1733-1804)
Discoverer of oxygen



PRIESTLEY'S LABORATORY

Although it may be an incorrect one, the mind demands an explanation of observed phenomena, and, in his efforts to satisfy this demand, Georg Ernst Stahl established the famous *Phlogiston Theory* of combustion. Stahl, who was physician to the king of Prussia, put forth the idea that all combustible substances possess a common principle, which escapes during the process of burning. This imaginary substance he called *phlogiston*. Substances that almost entirely burn up like coal were nearly

pure phlogiston. Metals were not elements but compounds, (composed of more than one substance) and when they were heated in the air, phlogiston escaped. To restore the metal to its original state it was necessary that the *calx*, as the new product was called, should take back its lost phlogiston. This was accomplished by heating it with carbon. The necessity of air as a supporter of combustion was explained by saying that there must be something to absorb the phlogiston. The fact that a candle is soon extinguished, when confined in a small space, was regarded as due to the saturation of the air with phlogiston, so that it could take up no more.

This was the first general principle enunciated in the history of chemistry, and it did seem to explain a large number of facts. For the first time it became possible to interpret and group a great variety of processes from one common viewpoint. And yet it was a false explanation. The chief difficulty encountered was the failure of the theory to explain the increase in weight resulting from the heating of a metal in the air. If phlogiston escaped, then the product should weigh less, not more, than the original metal. It was asserted, however, that phlogiston possessed the property of *levity*, or negative weight, and therefore with the loss of its buoyant effect a body should really weigh more. But no satisfactory explanation of combustion was given until Lavoisier appeared a half century later and, in a series of epoch-making experiments, put the phlogistonists to flight.

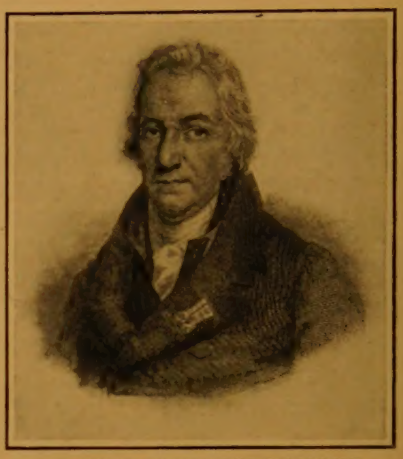
ANTOINE LAURENT LAVOISIER
(1743–1794)
Father of modern chemistry

The Pneumatic Period

Immediately following the early phlogistonists and preceding the dawn of modern chemistry, there appeared a most brilliant group of chemical investigators, whose numerous discoveries greatly enriched the subject and laid the foundations for the present period. I refer to Black, Cavendish, Scheele and Priestley. This is pre-eminently the period of *pneumatic chemistry*, for their work had to do largely with gases.

Joseph Black, for many years professor of chemistry at the Universities of Glasgow and Edinburgh, carried out a now classic research on the gas carbon dioxide, which he called "fixed air." He obtained it in a great variety of ways, and his investigations afforded much ground for the subsequent overthrow of the phlogiston theory.

Henry Cavendish, fellow countryman and distinguished co-worker



CLAUDE LOUIS BERTHOLLET
(1748–1822)
A co-worker with Lavoisier and discoverer of the important law of "mass action"

with Black, was one of the most eccentric characters in the history of science. Possessed of great wealth, he lived the life of a recluse, shunning publicity, and devoting himself to the most accurate and painstaking research. And yet his investigations were all made for his own personal satisfaction, and not at all for the advancement of science. Cavendish discovered hydrogen, which he called inflammable air, and regarded it as pure phlogiston. He proved the composition of water and, with an accuracy scarcely excelled by the most improved of modern methods, determined the percentage composition of air. He produced nitric acid by passing electric sparks through air, and came very close to the discovery of the rare element, *argon*.

One of the most brilliant investigators of all time was Karl Wilhelm Scheele, the first great Swedish chemist. Hampered by poverty throughout his life, and carrying on his experiments in an apothecary shop, Scheele's one passion was the pursuit of truth. In one of his letters he wrote, "*It is the truth alone that we desire to know, and what joy there is in discovering it!*" Among Scheele's discoveries was that of oxygen, made at least two years before Priestley's independent discovery of the same substance, but not published until a later date. He also discovered chlorine, so important in bleaching, and the first of the poisonous gases used in the great war. He discovered and studied many inorganic compounds and perfected new methods of analysis. But, with the insight of true genius, he made a host of brilliant researches in the realm of organic chemistry, and he may be regarded as the virtual founder of this important branch of the subject. He was a pioneer in every field of chemistry, and his untimely death at the early age of forty-three was a distinct loss to the science.

JOHN DALTON (1766–1844)
Propounder of the "Atomic Theory"

The name of Joseph Priestley will forever be associated with the discovery of oxygen, which he accomplished on August 1, 1774, by heating red oxide of mercury with the aid of a twenty-inch burning glass. By profession Priestley was a minister, but he early became interested in the study of gases, and devoted much of his life to this pursuit. He called his

JÖNS JAKOB BERZELIUS (1779–1848)
The "Czar of Chemistry" for half a century

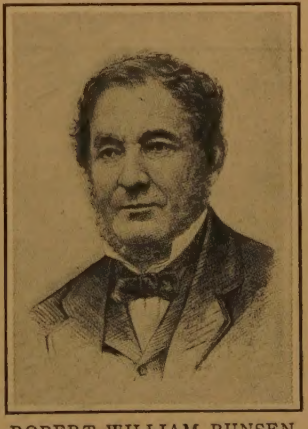
new gas "dephlogisticated air," because of the great brilliancy with which it supported combustion (which means that the gas produced and maintained burning). A mouse placed in it became much more lively, and he himself was greatly invigorated from breathing the gas. Priestley discovered that plants would restore to phlogisticated air, or air robbed of its oxygen, the power to support combustion. He also investigated and analyzed many other gases.

But strange as it now seems, none of this group of experimenters perceived that they were laying the ground work for a new theory of combustion. With the exception of Black, each remained a staunch phlogistonist to the end.

The Birth of Modern Chemistry

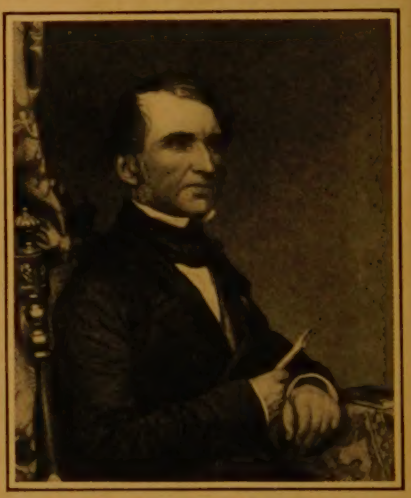
With the investigations of the illustrious Antoine Laurent Lavoisier (lah-'vwah-see-ay) and his genius for interpretation of previously discovered facts, we have the birth of *modern chemistry*. Born into a family of wealth, and given every advantage of education, Lavoisier at an early age established a well equipped laboratory and turned his attention to science. To his everlasting credit he attacked the problems of chemistry with the balance, and sought to establish the quantitative relations of chemical reactions. The first classic proofs of the fundamental law of the conservation of matter, *i.e.*, that matter can neither be created nor destroyed, we owe to his brilliant demonstrations. First of these was his famous proof that water cannot be transformed into earth. In a sealed glass vessel, he boiled pure water for one hundred days and at the end of that time found that the vessel and contents had not changed in weight. Thus nothing had been gained from the fire. The empty vessel had lost in weight, but the sediment from the evaporated water exactly equaled this loss, showing that the apparent formation of earth was due to the solution of glass by the water.

But Lavoisier's most important contribution to chemistry and the foundation stone of subsequent progress was his accurate and brilliant explanation of combustion. Learning from Priestley of dephlogisticated air and its



ROBERT WILLIAM BUNSEN
(1811–1899)
The first to use the spectroscope in chemical analysis

properties, he repeated Priestley's experiments, and, thereby, obtained the key to a number of previous observations. Lavoisier had heated a weighed quantity of tin in a sealed glass vessel, thus changing a portion of it into tin oxide. The vessel as a whole did not gain in weight, but, when Lavoisier opened it, air rushed in. This showed that the tin had united with something in the air. The increase in weight of the vessel and contents was now found to equal exactly the weight that had been gained by the tin. Therefore, Lavoisier rightly concluded that Priestley's newly discovered gas was the supporter of combustion and the cause of the increase in weight, when metals are heated in the air. Considering that this element is an essential constituent of all acids, he gave to it the name "oxygen," which means acid-former. Since this assumption, however, is not true, it proved a stumbling block for many years to a true knowledge of a number of elements. Lavoisier's *Elementary Chemistry*, containing his new ideas and a greatly extended list of elements and compounds, wrought a chemical revolution, and gave to the phlogiston theory its death blow. Having incurred the enmity of the Revolutionary Government, Lavoisier was guillotined in 1794, and chemistry lost the most conspicuous figure of the times.



JUSTUS VON LIEBIG (1803-1873)
Father of agricultural chemistry

Berthollet and Proust

The history of chemistry in the early years of the last century was marked by a keen controversy between two French chemists, Louis Berthollet (ber'-to-lay) and Joseph Proust, which resulted in the establishment of the fundamental law of *Definite Proportions*. Berthollet, denying the existence of this law, contended that two elements do not combine in definite proportions to form compounds, but said there might be any number of compounds produced by the combination of the *same two* elements. After a series of most accurate researches, covering a period of eight years, Proust conclusively demonstrated the falsity of this assertion. Since then the truth of the statement—"The composition of a chemical compound never varies" (which is the law of definite proportions)—has been proved by a host of investigators.

LOUIS PASTEUR (1822–1895)
Pioneer investigator of fermentation and contagious diseases

LOUIS JOSEPH PROUST
(1755–1826)

Dalton and the Atomic Theory

Passing over Sir Humphry Davy, whose work has been discussed in another place, the next great figure is John Dalton, the father of the Atomic Theory. This theory is the most important and far-reaching generalization in the history of the science, and is, even at the present moment, the guiding principle of chemical investigation. The son of a poor weaver and early left to support himself, Dalton became a school teacher and an earnest student of the physical sciences. From his study of gases and the determination of the compositions of a number of them, Dalton came to the conclusion that *elements are made up of smallest particles called atoms, and that chemical compounds of the elements are formed by the union of these atoms in simple numerical proportions.* This is the Atomic Theory. But the vast difference between this theory and that of the Greek philosopher, Democritus, rests upon the fact that Dalton came to his conclusions as the result of experimental work and not speculation. The theory helped to explain observed facts and led to the discovery of new ones. This is the supreme test of any hypothesis.

The Beginnings of Research

The foundation for the great researches of the last century had now been laid. A veritable paradise of chemical possibilities invited the investigator. New paths opened on every hand, and the atmosphere of Europe was alive with the spirit of scientific research. After the introduction of the atomic theory and an appreciation of the fact that, when the atoms enter into combination, they do so in proportion to certain definite relative weights, it became a matter of the utmost importance to determine these atomic numbers. No correlated knowledge of chemical compositions nor rational system of naming compounds could be possible without it. These numbers, too, are the most significant set of constants in the universe, and whatever the physicist may decide as to the ultimate particle of matter, for the chemist the atom will probably remain forever the practical working unit.

COUNT RUMFORD (1753–1814)
Born Benjamin Thompson, Woburn, Mass. Founder of the Royal Institution, London, and of the Rumford chair of Physics, Harvard University

The great Swedish chemist, Jons Jakob Berzelius, took up this task as his life work, and

with an unsurpassed zeal for accuracy and thoroughness enriched the science as hardly any other man has ever done. He did not confine himself to the determination of atomic weights alone, but developed every important branch of the subject. For nearly half a century he was the czar of chemistry. A wonderful teacher, he drew to his simple laboratories in Stockholm many who were to be great leaders in the years to follow. Not always correct in his assumptions, he was a creative genius of the first rank, and chemists will never forget the debt they owe him.

JEAN BAPTISTE ANDRE DUMAS
(1800-1884)
A great French chemist and a pioneer in organic chemistry

Great Chemists of the Last Century

Among the contemporaries of Berzelius was Gay Lussac, a brilliant French chemist, who discovered iodine and formulated the law of the combining volumes of gases. Two great German chemists, whose work extended for a quarter of a century beyond that of Berzelius, were Justus Liebig and Friedrich Wöhler. Liebig was a pioneer in the fields of physiological and agricultural chemistry, and, as a teacher, he was the first to give systematic laboratory instruction. Possessed of tremendous energy himself, he imparted his enthusiasm to his pupils, among whom he numbered the greatest chemists of the last century. Wöhler in 1828 made one of the most epoch-making discoveries of all time. He effected the first artificial preparation of an organic compound, and forever destroyed the belief that the production of such compounds is dependent upon a "vital force." He opened up the rich field of synthetic chemistry and did most important work in it. The life-long friendship of these two men is one of the most beautiful incidents in the history of the science.

Robert Wilhelm Bunsen, together with Kirchoff, in 1854 perfected the spectroscope, an instrument that not only affords the chemist his most delicate means of detecting elements, but also enables him to analyze the stars. Faraday, the pupil of Davy and his successor in the Royal Institution, was the first great physical chemist. He liquefied the first gases and formulated the fundamental relation between electricity and chemical action. In his laboratory may still be seen the small bottle of benzene, which was the first coal tar product ever extracted, and constitutes him the forerunner of a mighty industry. Dumas, a great French chemist, contributed much to theoretical and analytical chemistry, while his fellow-countryman, Louis Pasteur, has done immortal work on the chemistry of fermentation and the allied subject of contagious diseases. Kekulé and Van't Hoff, with their new theories of the constitution of carbon compounds, wrought a revolution in the domain of organic chemistry. Arrhenius, a distinguished Swedish chemist, has given us an electrolytic hypothesis of chemical action, scarcely less important and farreaching than Dalton's conception of the atoms.

The Periodic Law

But even with all this, the elements and their compounds had not been welded into a coherent system. No fundamental principle seemed to govern their relationships. There were aggregations of isolated facts but no law of harmony. Then came the Russian Mendelèeff and the German Lothar Meyer, who, independently of each other, discovered that, back of this seeming chaos, law and order reigned supreme. There was a system, and they had found the key. Their great generalization is known as the Periodic Law. They found that, if the elements are arranged in the order of

their atomic weights, natural periods result of approximately eight elements in each, and, here is the remarkable fact, the members of any particular period repeat in order the properties of the elements in the preceding period. In the language of Robert Kennedy Duncan, "Just as the pendulum returns again in its swing, just as the moon returns in its orbit, just as the advancing year ever brings the rose of spring, so do the properties of the elements periodically recur as the weights of the atoms rise." There were a few exceptions to the law, and a number of blank spaces in the table, but no one could doubt that back of this system stood a plan. One more step had been taken in unraveling the mysteries of the universe. The veil was drawn aside, and men seemed to catch a glimpse of the eternal purposes of the Great Architect.

So great was Mendelèeff's faith in this law that he predicted the discovery of three new elements to fit certain blank spaces in the table. Not only have these elements been discovered, but their properties are practically identical with those foretold by the great Russian chemist. Since then the discovery of other elements, as radium and the rare gases of the atmosphere, have been made, but they all take their natural places in accordance with their atomic weights. For the first time a general principle was seen to run throughout chemical phenomena and bind them into an intelligible system.

THEODORE WILLIAM RICHARDS
Professor of Chemistry at Harvard and the most accurate investigator in the field of atomic weights

A New Era in Chemistry

Within the last few decades the application of these great principles to the solution of chemical problems has ushered in a "new era in chemistry." The accidental knowledge of the Ancients grew into a system, and the system has become an organized science. Our new knowledge of radio-activity is giving us a deeper insight into the mysteries of the electrons and that vast realm of chemical activity within the atoms themselves. There appears to be little doubt that the electrons, those infinitely small particles which seem to compose the atoms of all elements, represent the primal stuff from which this universe has sprung and into which it may revert. That chemists will some day be able to control the activities of these electrons, is confidently believed, and the world would not be surprised at any moment to learn that the dream of the alchemist has at last come true.

SUPPLEMENTARY READING

HISTORY OF CHEMISTRY *By Ernest von Meyer*

HISTORY OF CHEMISTRY *By F. J. Moore*

THE STORY OF ALCHEMY *By M. M. P. Muir*

NEW ERA IN CHEMISTRY *By H. C. Jones*

ESSAYS IN HISTORICAL CHEMISTRY *By Sir Edward Thorpe*

THE NEW KNOWLEDGE *By Robert K. Duncan*

MODERN CHEMISTRY AND ITS WONDERS *By Geoffrey Martin*

*** Information concerning the above books may be had on application to the Editor of The Mentor.

THE OPEN LETTER

What is the meaning of the word "Chemistry," and what was its origin? We are told that *Chemia* is the ancient name for Egypt and that, since the art of working over metals in an endeavor to produce gold and silver—the art of "alchemy"—was practised first in Egypt, the term "Science of Chemistry" may have been used originally to mean the "Science of Egypt." Chemia also means "black and hidden," referring no doubt to the black soil of Egypt. Considering the word in this sense it seems possible that "chemistry" may have meant "black or hidden art." We find one authority noting that *chemia* means "black" and also that the first step in the ancient alchemist's experiments in changing metals was a process of *blackening*, the writer concluding from this that *chemia* may, at first, have simply meant the substance employed in blackening the metal—which was the so-called "philosopher's stone." He further states that ancient Arabic writers used the term *al kîmiyâ* to indicate, not the art itself, but a substance employed in the art. The Arabs got the word from Egypt when they over-ran that country in the seventh century. The Arabs appropriated the mystic processes of the Egyptians, and gave the name *alchemy* to the art of making gold and silver out of baser metals. The prefix *al* is the Arabic for *the*, and we still have it preserved in such chemical terms as alcohol and alkali.

★ ★ ★

Today we live in the age of creative chemistry. The great forces of Nature are yielding up their secrets, and the chemist and the physicist are harnessing them to the performance of the world's work. Chemistry is the mightiest resource both of peace and war. There is no industry which does not have its chemical problems and scarcely a phase of human activity which chemistry does not touch. Like the wizard that he is, the chemist fabricates substitutes for basic materials such as cotton, copper, rubber and wool. In his furnaces he obtains temperatures rivaling those of the sun and with each new advance he makes fresh conquests. The Great War was simply a tremendous contest between chemical forces. From the poisonous gases, the high explosives, the armor plate and the big guns, to the healing drugs of the hospitals and the fertilizers for the production of food stuffs, it was all a matter of chemistry. More to be dreaded than Germany's armies were the chemists in the laboratories. But now that peace has come the problems of the chemist are none the less great. With the energy of the alchemist, but the genius of true insight, he is applying himself to their solution and achievements surpassing anything yet done are doubtless within his grasp.

★ ★ ★

We have had our troubles during the last six months—a nine weeks' printers' strike during which not a word of Mentor material could be put on a press, then labor trouble that took the form, in one instance, of a deliberate and mischievous mixing-up of Mentor text and pictures, and, finally, delays and difficulties in postal service and transportation. We have worked our way through the "briars of distress" and are, at length, on the highway again, and on our regular publishing schedule. For a good-natured patience beyond parallel, I believe, in periodical publishing, I want to thank The Mentor members from the bottom of my heart. The best asset The Mentor has—and it is a priceless one—is the good will of its readers. It has meant everything to us during these months of sore trial. Letter upon letter has come in, with an anxious call for missing Mentors and Mentors a month late, and, in so many of these letters, there has been the considerate clause: "I suppose it's the printers' strike. I'm sorry—but I *do* want my Mentor." One cry from far-off Seattle struck home with an appeal that ought to move the heart even of a union printer. "I *want* my Mentor," a young reader wrote, "I have been like a child wandering alone in the dark without it." The most cheering thing in our work is the fact, made clear in the mail every day, that The Mentor is regarded, not simply as a bit of entertaining literature but as a *necessity* in the development and improvement of one's self.

W. D. Moffat

EDITOR

ONE

THE story of chemistry presents no more picturesque figure than that of the alchemist, whose mystic spell held in rapt fascination the imagination of both king and peasant, and, for many centuries, shaped the course of all things chemical. Working over his pots and retorts in crude laboratories and dark caves, shrouding in deepest mystery his secret activities and exercising an almost infinite patience, this blind groper after the unattainable sought with the zeal of a religious fanatic to find or make the Philosopher's Stone. The fortunate possessor of this magic "Essence" might at once obtain those two highest goods—wealth and health—and also, with its continued presence, elevation of character and spiritual refinement.

Thoroughly imbued with the ancient proverb, "As above, so below," the alchemist firmly believed in the transmutation of metals (changing of one metal into another) and the prolongation of life. To the inorganic kingdom, the metallic ores, existing beneath the surface of the earth, he applied the laws of organic growth and decay which he observed in the world above. Just as animals and plants grew, so did the metals, and by cultivation and proper environment they, too, might be brought to perfection. He thought of all metals as slowly growing toward the perfect state of the noblest of them all—gold. This belief was a part of his religious faith, and he had no doubt that there awaited the fortunate discoverer a magic way of realizing this natural striving toward perfection.

In support of this theory of the changing of one metal into another, did he not have an abundance of evidence? Were not gold and silver actually found in lead ore? And what more natural than to suppose that these precious metals were transmuted lead. Worked-out mines were reputed, after long periods of time, to exhibit new "crops" of gold and silver. Crude lead when heated in an open crucible of bone, slowly changed to a cinder, which disappeared in the crucible, leaving a button of metallic silver. Iron rusted, and a new substance formed. If copper were dissolved in nitric acid, and an iron rod thrust into the solution, the iron disappeared and metallic copper formed in its place. Was this not the transformation of iron into copper, and why should it not be equally possible to transmute baser metals into gold? Mercury falling in rain upon melted sulphur changed to a black substance which, when distilled, yielded a beautiful red solid. In an age of superstition and utter ignorance of the underlying principles of chemical action, is it very surprising that the alchemist should have had implicit faith in the possibility of transmuting the metals into gold?

Just as man possesses body, soul and spirit, so did the alchemist believe in a three-fold nature of the metals. Symbolic of these three aspects were, Principles, peculiar to each substance; Elements, characteristic of many substances; and the Essence common to all. There were three principles—Sulphur, Mercury and Salt—and four elements—Earth, Water, Air and Fire. Everything was produced by the four elements through the mediation of the three principles, and the essence was the common spirit of all, which must be obtained in order to effect the great transmutation. The metals possessed this essence in varying degrees. Gold, the noblest metal, was thought to be nearly pure essence and yet, so masked was it, as to be almost impossible of separation. In order to change a baser metal into gold, it was necessary to purge away its body, the dross, by many processes of purification. Although this happy result might be obtained without the Philosopher's Stone, yet the possession of a small portion of this magic substance transmuted all matter into finer gold than that of the mines.

To a degree unequaled elsewhere in all history the lure of this mythical substance enchanted every class of society and turned into a narrow and unworthy channel the course of a great science. But the alchemist in time became the chemist; and the chemist has today very nearly become the alchemist.

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SIR HUMPHRY DAVY

THE STORY OF CHEMISTRY

Sir Humphry Davy and the Royal Institution

TWO

IN Sir Humphry Davy, the youthful but gifted Professor of Chemistry at the Royal Institution of London, the new-born science of modern chemistry found an investigator whose brilliant discoveries did more to shake off the last lingering fetters of alchemy and stimulate intelligent research than the work of any other man before or since. The Royal Institution had been founded by Count Rumford, an American Royalist and soldier of fortune, in 1799. In the following year Davy, whose work on nitrous oxide, or laughing gas, had made him famous, was invited to become assistant professor in the newly established institution. Davy, then in his twenty-second year, accepted, and was shortly after made full professor, a position which he held until 1813 and in an honorary capacity until his death in 1829. Davy was born in 1778, in Penzance, Cornwall, England, the son of a wood-carver.

Mentally keen, of great personal charm, endowed with a capacity for thorough investigation and possessing the faculty of lucid statement, coupled with the gifts of real eloquence, Davy was splendidly equipped for the great tasks before him. Seldom has a man been endowed with richer opportunities. He stood at the dawn of a new day in chemistry and vast realms of unexplored truths beckoned him. The atmosphere of every European capital fairly tingled with suppressed interest in all things scientific. The new force of galvanism, or voltaic electricity, had taken the popular imagination by storm and new wonders were eagerly anticipated. To the satisfaction of this interest Davy applied himself with an enthusiasm and a genius for discovery unsurpassed.

His great researches, which he gave to the public at intervals in popular lectures, can be sketched only in barest outline. His first important work was to settle for all time the real nature of the electrolysis of water and to prove that the passage of the electric current through pure water yields nothing but hydrogen and oxygen. In common with Lavoisier, Davy believed that the two substances known as potash and soda were not elements but compounds of oxygen and unknown metals. To the determination of this question he next applied himself with his characteristic energy and enthusiasm. In this memorable research he employed a powerful voltaic battery. Upon a disc of platinum connected with the negative side, he placed a piece of pure potash, which had been exposed to the air long enough to become moist and therefore a conductor of electricity. In contact with the upper surface of the potash he placed a platinum wire leading to the positive pole. A vigorous action immediately followed with the liberation on the platinum disc of bright globules of molten metal, resembling quicksilver, some of which burned with a brilliant flame. So delighted was Davy when he first saw the appearance of the new metal that he could hardly contain himself and danced around the room for sheer joy.

He named this metal "potassium" and soon after discovered a whole galaxy of new elements—sodium, barium, strontium, calcium and magnesium. He was the real founder of the great processes of electrochemistry and a host of modern industries. But little did he dream of the tremendous results that would flow from this important service to science.

In one of the most able and conclusive researches of his whole career Davy proved that the important gas chlorine, which he also named, is not a compound of oxygen and some other element, but undoubtedly an element itself. Although he did not discover iodine, he did the most important early work upon this element and established its character as we know it today. He also experimented with hydrofluoric acid, the explosive nitrogen chloride, and rendered distinguished service in many other lines of chemical research. One of his greatest benefactions was the invention of the miner's safety lamp, which has saved thousands of lives in the coal mines of England and America.

In his untimely death at the age of fifty-one chemistry lost an investigator of the highest rank and a man of rare genius.

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SIR WILLIAM PERKIN

THE STORY OF CHEMISTRY

Sir William Perkin and the Coal Tar Products

THREE

ON that memorable day in 1856 when William Henry Perkin, then a lad of eighteen, discovered the first coal tar dye, little did he dream that he was unlocking the door to a veritable treasure-house of chemical wealth, the full extent of which is not yet known. In that moment he stood at the beginning of a new industry—yes a score of new industries. Across the countless centuries of the past came the aromatic breath of tropical forests and the gorgeous colors of a fossilized vegetation. Before him in endless procession stretched the myriad host of coal tar products.

As a student of chemistry in the Royal College of London, his native city, young Perkin had been assigned the task of preparing quinine from coal tar. One day, as he poured alcohol into a dirty black mess of aniline oil and other chemicals, there flashed into view a beautiful purple color. Being possessed with the true spirit of chemical research, Perkin set to work to isolate this color substance, and, very shortly, obtained mauve, the first of the aniline dyes. Additional research yielded the method of its preparation, and so contagious was Perkin's enthusiasm that he persuaded his father and brother to set up a factory for the manufacture of the new dyestuff. With no previous experience in such work, he overcame all obstacles and placed his product on the market. A few years later, from another coal tar derivative, he extracted alizarin, the brilliant "turkey red," which, for many years, had been a vegetable dye, obtained from the madder plant. That event sounded the death knell of the madder plant industry, and the millions of acres devoted to its cultivation were made available for the production of food. Anthracene, the coal tar base from which alizarin is made, and formerly regarded as pure waste, rose in value from practically nothing to $500 a ton.

News of these discoveries spread throughout the world, and the chemists in other countries went to work, particularly in Germany. The production of gorgeous colors of every shade and hue followed with kaleidoscopic rapidity. Dye works sprang up everywhere, and, to supply the chemicals needed in them, many other plants were called into being. But since neither the British Government nor its universities gave any encouragement to the new industry, it passed largely under German control.

The next great triumph of the coal tar chemists was the preparation of synthetic indigo. Indigo is as old as the Pharaohs of Egypt, for their mummies are found wrapped in cloths dipped in this ancient dyestuff. But, in 1879, Adolph von Baeyer, a famous German chemist, produced indigo artificially from coal tar. Immediately the dye works of the *Badische Annilin und Soda Fabrik* attacked the problem, and after fifteen years of exhaustive research by an army of trained chemists, and the expenditure of millions of dollars, synthetic indigo at a few cents a pound became a fact. The value of the annual crop of the indigo planters quickly dropped from $20,000,000 to $300,000.

Today nearly two thousand coal tar dyes are known, covering every imaginable hue, and meeting every requirement of taste and fashion. Millions of capital and thousands of men are engaged in the industry. And all this from a black, foul-smelling stuff that, but a short time ago, was regarded as an unmitigated nuisance, and, for nearly a hundred years, treated as pure waste. But coal tar is more than a source of dyestuffs. It is a tremendous resource both of peace and war. From it the chemist draws the explosive that wounds and the balm that heals. Like a magician he makes it yield the most delicate perfumes known to Nature. In it the physician finds an inexhaustible storehouse of powerful drugs for the stilling of pain, the allaying of fever, antiseptic uses and bloodless surgery. From this unsightly stuff is produced a sweet, five hundred times sweeter than honey. Here, too, the photographer comes for his great variety of developers and exceedingly sensitive preparations for films and plates.

Surely no magic realm ever yielded more in the imagination of the most fanciful dreamer than has coal tar to the touch of the research chemist. From that happy accident that led Sir William Perkin to the discovery of mauve has flowed a tremendous Niagara of chemical wealth and knowledge.

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ALFRED NOBEL

THE STORY OF CHEMISTRY

Alfred Nobel and Modern Explosives

FOUR

EVERY volley that swept the shell-torn battlefields of Europe during the late war bore terrible testimony to the inventive genius of Alfred Nobel, the Swedish chemist and engineer, who first made possible the enormous production of high explosives without which modern warfare would be impossible. Educated in America as a mechanical engineer, under the tutorship of John Ericsson of Civil War fame, Nobel returned to his own country and, devoting himself to chemistry, erected in 1863 the first plant for producing nitroglycerin in large quantities. This was one of the boldest steps ever undertaken, but Nobel had invented a very simple and comparatively safe method of manufacture, and he possessed the courage to put it into operation. The use of this new and most-powerful blasting agent quickly spread throughout Europe and America. But so many accidents resulted from the premature explosion of the treacherous stuff, including railroad trains, ships and even Nobel's own factory, that transportation companies refused to handle it and Governments prohibited its use. Nobel, however, was undaunted. He built another plant, and one day a lucky accident solved his problem of transportation and insured the future of high explosives. As he was removing some cans of nitroglycerin from a wagon, he discovered that some of the stuff, which had leaked from a broken can, had been entirely absorbed by the sand in which it was packed. This gave him the idea of making dynamite, which is both safer to handle and less violent in its action.

From the battle of Cressy to the Armistice of 1918 the world's wars have been fought with explosives having as an essential ingredient of their manufacture nitric acid. This is why the nitrogen-from-the-air plants were of such strategic importance in the Great War. As its name indicates, nitroglycerin is a compound of nitric acid and glycerin, the latter being a by-product of soap manufacture. Its very great explosive violence is due to the fact that the molecule of nitroglycerin contains within itself the oxygen necessary for its own combustion. Yet nitroglycerin will not explode unless it receives a certain sympathetic vibration, such as that produced by the explosion of a fulminate of mercury cartridge. Miners have been known to thaw out frozen nitroglycerin placed in a frying pan over a fire without mishap.

About the same time that nitroglycerin was invented, another powerful explosive appeared. This was guncotton, made by treating cotton, or some other form of cellulose, with a mixture of nitric and sulphuric acids. The light fibrous product had to be dissolved in alcohol and ether so as to form a plastic mass suitable for molding into rods and cutting into grains. In 1878 it occurred to Nobel that here were two explosives—one a liquid that had to be absorbed in a porous solid, and the other a solid that had to be absorbed in a liquid. Therefore, he dissolved guncotton in nitroglycerin and obtained blasting gelatin. Mixed with five per cent. of petroleum jelly, it forms cordite, an ideal explosive for big guns.

Another modern explosive is picric acid, much used in the late war. It is a yellow crystalline solid, made by acting upon carbolic acid with nitric and sulphuric acids. When shells containing it burst, they not only do terrific violence, but also liberate large volumes of exceedingly poisonous gases.

The explosive, however, that has appealed most to the popular imagination is T. N. T., or trinitrotoluol. Like picric acid this is a coal tar derivative made by treating toluol with nitric and sulphuric acids. This is a very "safe" explosive. It may be ignited, pounded with a hammer or riddled with bullets without danger. But when it receives that particular sympathetic vibration from a percussion cartridge there begins the wild dance of the atoms and the liberation of vast quantities of pent-up chemical energy. Before its terrific onslaught, concrete and steel are as chaff in the wind.

Explosives are not wholly destructive. They have their uses in peace as well as in war. Vast mining operations, great railroad tunnels and the building of a Panama Canal bespeak their beneficent services to mankind. As all the world knows, too, Nobel left the millions he made from these inventions for the promotion of peace and scientific progress. Nobel was born at Stockholm in 1833, and died in 1896.

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SIR WILLIAM RAMSAY

THE STORY OF CHEMISTRY

Sir William Ramsay and the Rare Gases

FIVE

THE discovery of the rare gases of the atmosphere—five new elements—constitutes some of the finest experimental work that has ever been done, and will forever mark Sir William Ramsay, the master genius of this brilliant research, as one of the greatest chemists of all time. From the days of Scheele, Priestley and Lavoisier to the closing years of the last century, the constituent elements making up the atmosphere were regarded as absolutely known. Indeed, in no other branch of chemical investigation had the great pioneers of the science done so much original and accurate work. More than a century before, Cavendish had determined the percentage of the principal constituents with a precision scarcely excelled by the most refined methods of today. Therefore, the announcement of 1895 of the discovery of a hitherto unsuspected element in this worked-out field of chemical research was received with very great interest and a certain amount of scepticism.

The clue leading to this important work was obtained by Lord Rayleigh in an investigation of the densities, or relative weights, of a number of gases, the oxygen and nitrogen of the atmosphere being among them. In his determinations of the density of nitrogen he made a discovery which to a mind less critical than the keen perception of the trained scientist would have passed unnoticed. Lord Rayleigh found that nitrogen obtained from the air was persistently heavier than nitrogen prepared in the laboratory from chemical sources. To be sure of this fact, he prepared nitrogen in a great variety of ways, but always with the same result. True, the increase in weight of atmospheric nitrogen over the gas artificially prepared was only 1 part in 200, but since this was fifty times greater than the maximum allowed for experimental error, it demanded explanation. A number of reasons immediately suggested themselves, all but one of which were quickly eliminated. The only conclusion possible pointed to the presence in the atmosphere of one or more unknown elements.

Sir William Ramsay (born in Glasgow in 1852) requested and was granted permission to make the investigation which should determine the truth or falsity of this supposition. In a series of now classic researches, the magnitude and exacting character of which only the trained scientist can appreciate, he succeeded after a few months in isolating a new element. He did this by passing atmospheric nitrogen, from which all the other constituents of the air had been removed, to and fro over heated magnesium metal contained in glass tubes. Since nitrogen combines chemically with magnesium, if there were any element present that would not thus combine, it would be left as a residue. And this Ramsay found to be the case. The new gas comprises about one per cent. of the atmosphere, and because it was found to have absolutely no chemical affinities Ramsay named it "argon," meaning "lazy." Examined with the spectroscope, that marvelous detector of even minute quantities of an element, there was disclosed in the spectrum the bright line of a new gas.

In 1868 the spectroscope, which detects the elements in the distant stars with as much accuracy as it does those in the chemist's laboratory, had revealed in the atmosphere of the sun an element unknown on the earth. Sir Norman Lockyer named this gas "helium," and in 1895 Ramsay obtained it from certain rare minerals. Next to hydrogen it is the lightest element known.

Convinced now of the existence of an entire family of new elements, Ramsay began a vigorous search for their whereabouts. All his investigations, however, were unsuccessful until 1898, when, by separating the constituents of liquid air, he found helium and three new elements to which he gave the names of *neon*, "the new one"; *krypton*, "the hidden one," and *xenon*, "the stranger."

These gases exist in the atmosphere in very small quantities and, like argon, are entirely lacking in chemical affinities. Recently it has been discovered that helium issues from the earth in certain places and, being non-inflammable, it is used as a substitute for hydrogen in filling airships. Argon, too, is now extracted from the air in large quantities and is used in place of nitrogen to fill electric lamp bulbs, because its presence increases very largely the candle power of the lamp.

Every element, however rare, undoubtedly has its use and, could we but find the key, their purposes would all be plain. In the great harmony of Nature each has its part to play and, at the touch of the master artist, will respond to the world's need.

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MADAME MARIE CURIE

NO other discovery of science has opened wide the doors to such tremendous possibilities for insight and knowledge of the underlying mysteries of the universe as that of radioactivity. It changed the trend of a century of scientific thinking and has revolutionized our whole conception of atoms, elements and matter. Toward the close of the last century came one of those tidal waves of human achievement, that here and there set the bounds between great epochs of scientific progress. Among many such triumphs of the first rank was the discovery of the X-Rays by Roentgen, in 1895, and the beginnings of radioactivity.

To the man of genius this discovery afforded clues to new fields of investigation, and Professor Henri Becquerel of Paris was such a genius. He immediately began to experiment with phosphorescent substances in general in an effort to discover whether they, too, might not be radioactive. Of all the substances examined, the element uranium was found to possess this new property in highest degree. In one of those rare moments of scientific discovery, Becquerel wrapped a photographic plate in heavy black paper, placed a key upon it and over the whole suspended a piece of uranium. These were left in perfect darkness for twenty-four hours. Then Becquerel developed the plate and there, clear as sunlight, was the image of the key. Uranium did give off rays capable of penetrating opaque matter. Against the background of the Ages a new fact of Nature stood forth, and man had found one more clue to the eternal mysteries of energy and matter.

At the suggestion of Becquerel, Madame Skaldowska Curie and her husband, Professor Pierre Curie, undertook their now classic investigation of pitchblende, the parent mineral from which uranium is obtained. To their delight, a delight known only to the disinterested searcher after truth, they found that pitchblende possesses a radioactivity four times greater than that of uranium itself. This could have but one meaning. Pitchblende must contain in small quantities some new substance of very great radioactive powers, and to the task of isolating this substance the Curies addressed themselves. As the result of a prodigious amount of work, unequaled in the annals of chemical analysis, they succeeded in extracting from several tons of the ore a few hundredths of a gram of a substance, a million and a half times more radioactive than uranium. This new element was radium.

Here was not merely the discovery of a new element, but a hitherto undreamed of variety of the most interesting and baffling chemical phenomena. This element emitted X-Rays, produced phosphorescence in many substances, had powerful chemical and physiological effects and was able to render gases conductors of electricity. But more than this the radium atom was found apparently to disintegrate with the liberation of vast quantities of heat and the formation of the element, helium. Here was natural alchemy. Although powerless to stay or accelerate the process, radium under our very eyes gives birth to another element. Its life history is about 2,500 years and the end-product of its disintegration is thought to be lead.

Its great manifestation of heat is due to the liberation of the vast quantities of energy locked up within its atoms. Atoms are now regarded as being "solar systems," of infinitely small particles of negative electricity rotating with enormous velocities about centers of positive electrification. In these rapidly moving electrons we have the source of the subatomic forces of which Sir Oliver Lodge and other scientists speak. Could we tap it, infinite reservoirs of energy would be at man's disposal. That this dream may be the fact of tomorrow is not beyond the realm of possibilities.

Radioactivity has opened many other roads to the truths of Nature which here we cannot even glimpse.

Madame Curie, born in Warsaw in 1867, received her preliminary education in the Polish capital and in Paris. Upon the death of her husband in 1906, she was appointed to his place as a member of the faculty of sciences in the College of the Sorbonne, University of Paris, and, later, to the position of chief professor of physics. In 1911 she received the Nobel Prize for chemistry.

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THE END OF ALCHEMY

ALCHEMY, among scientific men—at least in England—came to an end with a tragedy. James Price, a distinguished amateur chemist of the 18th century, and a Fellow of the Royal Society of England, imagined that he had succeeded in compounding a powder that would convert mercury or any other of the baser metals into gold or silver. This amazing claim, coming after years of alchemy experiments and failures, created, naturally, a tremendous sensation. Mr. Price was a man of repute—not a quack—and when he communicated his discovery to his scientific friends, a discussion followed that made it necessary for him to demonstrate without delay by making gold in the presence of a select assembly of men of rank and science. Mr. Price's experiments, seven in number, were commenced on the 6th of May, 1782, and ended on the 25th. In all these experiments gold and silver were apparently produced. Some of the gold was presented to George III, King of England, who received it with gracious appreciation. The University of Oxford bestowed a degree upon Price; and his work, containing an account of his experiments, ran through two editions in the course of a few months. Then came a fierce conflict in the press, and, finally, the Royal Society felt it necessary to call upon Price, as a Fellow of the Society, to prove to his associates that he could really make gold. Publicity seemed to overwhelm Price to such an extent that he lost confidence, and, for a long time, he tried, in various ways, to evade the test. He declined to renew his experiments on the ground that, although he had made a valuable discovery, it was not of practical value, since the cost of manufacturing gold in this manner was greater than the value of the gold obtained; that it would cost 17 pounds sterling to make only one ounce of gold.

His excuses, however, were of no avail. Sir Joseph Banks, president of the Royal Society, pointed out to Price that his own honor, and the honor of the leading scientific society of the world, were implicated. Price was forced, finally, to make some more of the precious powder so as to satisfy the Royal Society. He asked to be permitted to go to his laboratory at Guildford for a few days to prepare for the great test. He left London in January, 1783, and, when he arrived at Guildford, he closeted himself in his laboratory, where his first employment was to distil a quantity of laurel-water in a mysterious way. Then he commenced the preparation of his magic powder.

After six months he invited the members of the Royal Society to meet him at his laboratory. By that time sentiment had gone strongly against Price. Three members alone accepted the invitation. Price received them with cordiality, though he seemed to feel acutely the want of confidence implied by there being so few. When the time had come to begin the experiment, he stepped quickly to one side for a moment, raised the flask of laurel-water, bowed to his friends, and swallowed the contents. His visitors, seeing an immediate and shocking change in his appearance, called for medical assistance—but it was too late. The laurel-water had been distilled with one of the quickest and deadliest of poisons ever known, and in a few seconds the unfortunate man was dead.

It can never be fully ascertained whether he was himself deceived, or whether he wilfully deceived others; but Alchemy in England thus ended in a sensational and tragic manner.

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